DOCUMENT RESUME

ED 180 447 IR 007 921

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TITLE Aptitude, Learner Control, and Adaptive Instruction.
PUB DATE Apr 79
NOTE 25p.: Paper presented at the Annual Meeting of the American Educational Research Association (San Francisco, CA, April 1979)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Computer Science Education: Educational Research: Higher Education: *Individual Differences: *Individualized Curriculum: *Individualized Programs: Programing Languages
IDENTIFIERS *Adaptive Instruction

ABSTRACT

In addressing the question of whether learner control of instruction can accommodate individual differences, this paper discusses some characteristics of learner control, including those conditions of learning which the student can control and those imposed by society and its institutions which are not under individual control. Studies of attempts to accommodate individual differences by various methodologies are reviewed, and a more detailed description is provided of a study of BIP, an interactive computer course on computer programming offered at Stanford University. This course, which involved university undergraduates who spent 15 hours learning the BASIC computer language, is cited as an advanced example of learner controlled instruction. The BIP program is designed to keep detailed protocols of each student's learning activities, thus providing intermediate measures to describe individual differences in learning activities that may contribute to success or failure in the course. Findings of the study indicated that individual differences in learning increased over the duration of the course, that a multidimensional scaling of the correlations among learning activity variables showed a clear circumplex structure, and that measures of learning activities, rate, and outcomes were strongly predicted from initial aptitude differences. Summary conclusions suggest that learner control does not accommodate individual differences. (RAO)

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APTITUDE, LEARNER CONTROL, AND ADAPTIVE INSTRUCTION

by

Richard E. Snow

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This symposium addresses the question: Can learner control of instruction accomodate individual differences? My answer to this question is: No!

This answer is more of a prediction than it is a summary of evidence, since noone would claim today that enough research has already been done on the question to justify a clear answer. But a good deal of evidence already exists on related questions to justify my prediction, I think. In my presentation today, I will review some of this evidence and then try to suggest very briefly a course for future research on learner control that will avoid its demise when it turns out not to be a panacea for individual differences.

An historical observation seems appropriate here. What some see as the "onward march" of educational research over the decades has been characterized by some others, including myself, as more like "a random walk through the panacea garden." Each few years a new plan or approach to some major educational problem becomes the fad to replace the one found wanting just before. We have ourselves to blame for public or political skepticism each time we behave as though the newest idea offers a simple solution to an old educational problem heretofore seemingly intractable. We learn a lot as we move along this path, but we also lose a lot: The public sees only the succession of naive overgeneralizations and unfulfilled promises. And federal agencies move on to fund the next educational promise. Let us not allow the good ideas in research on learner control to be lost in this process.

Let us look now at the broad context of the problem. Genetic and environmental diversity produces diversity in human learning and performance. And, diversity among humans appears to expand as age and experience accumulate. This is a fact for psychology and a problem for education.

There are some further psychological facts to face at the outset. Among the diverse individual differences that might be observed to vary among human learners, some have been indexed by standardized psychometric measures. Some of these so-called aptitude indices consistently correlate with learning outcome in formal instructional settings. That is, in almost any instructional setting, some learners do well, some do poorly, and the difference is predictable from measures taken before instruction begins. Another fact is that some of these aptitude indices consistently interact with variations in the instructional settings presented. That is, the degree to which learning outcome is predictable from premeasures varies across instructional settings. But no instructional setting has ever been designed in which the correlation between these premeasures and learning outcome is consistently found to be zero.

Research on accomodating individual differences has its own procession of panaceas. The Dalton and Winnetka plans of the 1930's were early attempts to accomodate individual differences. Programmed instruction, computerized instruction, aptitude-treatment interaction, mastery learning, the Keller Plan, etc., etc., have each in turn been hailed as the new answer to the individualization problem. Research with these approaches, however, has failed to show that any can be counted upon consistently to erase the role of initial aptitude differences in later learning from instruction.

Now comes learner control. There is much to be said in favor of giving learners increased control over the conditions of their own learning. It is nice to think that students learn how to be independent learners by being given increasing autonomy in decisions about the instructional conditions they must negotiate. Presumably, feelings of self-efficacy and self-determination,

and the skills involved in self-evaluation and the taking of independent responsibility are enhanced by experience with control. These are important goals of education for the individual. But can learner control be expected to overcome the persistent fact that individual characteristics not under the control of the individual will determine to a significant extent what and how much that individual will learn in a given instructional setting? I think not.

The context within which the issue of learner control needs to be considered includes also issues concerning choice of instructional goals and instructional content, and the recognition that learner control can take many, many forms. First, one can distinguish two broad categories of instructional goals (following a similar distinction by Cronbach, 1967). There are individualized goals, that is, goals chosen by individuals themselves for their own purposes. The most obvious examples are the elective courses available in most schools and colleges -- music, art, home economics, foreign language, etc. There are also goals imposed by society or its institutions. The common minimal expectations in reading, writing, and arithmetic are examples.

Learner control is clearly an important aspect of the individualized goal category; neither institutions nor parents ought to assign electives, though they may stipulate minimum levels of achievement to be expected once a course of study is elected. The individual's choices in this category are in a sense manifestations of aptitudes, either aptitudes the individual wishes to exercise or which he or she wishes to acquire. A great deal of learner control over the conditions of instruction might be tolerated in this individualized goal category. Here, optimization of learning may not always be the primary

concern; the value of learner control for its own sake looms large.

In much of public education, however, the goals are imposed by the institution, and here is where accomodating individual differences for the purposes of optimization becomes most important. If there is some attempt at individualization in these instances, the content of instruction may to some extent be variable from learner to learner. Content can also be entirely fixed, along with goals, by the institution.

It is possible also to distinguish several rough levels of learner control, even though the variety of forms learner control might take is immense. Learners can have complete independence, with or without checks on progress, and specified resources for them to turn to. The instructional program may impose task conditions, but within this allow several degrees of freedom for learner control over pace, choice of alternative treatment conditions, etc. Or, in the most limited case learners are given control only of pace, or access to remediation, or both, or neither.

In Table 1, the condition in which there is complete learner control over everything is identified as the "adult scholar model." This is the ideal toward which we hope each learner will strive and ultimately achieve. The condition in which the learner has no control over anything is called the "child robot model." This condition is unfortunately still characteristic of many elementary schools today. What we should be most concerned about in this symposium is the column in which goals are prescribed but instruction is to some extent individualized, so content is to some extent variable. In this column are listed six sources of evidence associated with different degrees or levels

of learner control; these are regarded as a reasonably representative sampling of the possibilities identified in that column. Each is reviewed below briefly, with the order alternating between the top and bottom of the column, so as to zero in on the so-called "BIP study," which will receive the most attention.

Table 1 here

Programmed instruction (PI) was an early attempt to accomodate individual differences. It gave learners control over the pace of instruction, and little else. It also failed miserably in its goal. Slow learners rarely matched fast learners in ultimate criterion performance, on average, while many fast learners performed less than optimally because of the boredom resulting from the miniature step-by-step sequence. (See Cronbach and Snow, 1977, for a detailed review of PI studies in relation to individual differences.)

The Maastricht study, an evaluation of an innovative medical education program in Maastricht, Netherlands, is still in progress. Some of the preliminary date, (Wijnen and Snow, 1975; also discussed in Snow, 1977) are shown in Figure 1. These learners had control over virtually all conditions of learning except the goals. In Figure 1 a, the regression of the first 4-week achievement test on initial verbal ability scores is shown. The correlation associated with this slope was r=.48. Note that some high ability students did less well than predicted; it is believed that this occurred because they would have preferred to work alone rather than with the peer discussion groups to which they were randomly assigned. In Figure 1 b, representing the fifth 4-week achievement test some of these students had by now exercised their environmental control to succeed in independent work despite the peer groups, while some middle-

ability students, who had indicated that they preferred peer-cooperative learning earlier, have begun to drop behind as the going got tough. The correlation between aptitude and achievement in Figure 1 b is r=.56. Note that these data depict performance after 20 weeks in an instructional program that is highly learner controlled. In short, it took ability and some degree

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Figure 1 here

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of independent task orientation to succeed in this environment. Learner control of the sort available at Maastricht looks significantly less than optimal for many students.

The Greene study (also discussed in Snow, 1977; for all details see Greene, 1976) used an imposed task in nine elementary classrooms, but gave a random half of each class choice over when and for how long they would work on the task, and how they would evaluate themselves. Figure 2 shows the regression of outcome on initial aptitude at the half class level. That is, these are between half-class regression slopes. The figure suggests a marked interaction. Choice was best for learners in high-average ability classes; no-choice was best for learners in low-average ability classes. The interpretation is limited, of course, to this sort of situation, in which each half-class could see the conditions that were experienced by the other half of the class. And, we would need many more classes to be confident about the regression slope estimates. Nonetheless, the data argue strongly that learner control over task performance conditions is clearly not best for everyone.

Figure 2 here

There have been a number of so-called "preference studies" in which learners were given their choice among several alternative instructional treatments, having sampled some of each. These were summarized by Cronbach and Snow, 1977. In contrasts between preferentially chosen treatments and assigned treatments, several investigators failed to find an advantage for giving students preferential choice. A few studies have shown some advantage for assigning preferred treatments, but the results are weak and mixed at best. "All in all..." Cronbach and Snow (1977) concluded, "the evidence discourages the romantic view that self-selection of the instructional diet pays off." (P. 478). Incidentally, a new study just completed by Peterson (1979) showed that students who preferred small group to large group instruction did less well in small groups than in large groups. This harks back to the Maastricht study.

Atkinson (1972) reported data from a computerized instructional situation, showing that sequences chosen by optimization rules within the computer were more effective in producing learner outcome than were sequences of items chosen by the learners themselves. Once again, then, learner control did not produce optimum learning.

The data I would like to concentrate upon now were collected within a study of an interactive-computer course on computer programming. The course can be regarded as an advanced example of learner controlled instruction. The study was conducted within a long-term project on the analysis of aptitude in relation to learning activities and processes. Keith Wescourt and Janet Freitas are coauthors with me of a technical report on the study, which can only be summarized briefly here.

Stanford undergraduates (N=28) spent 15 hours learning BASIC computer language in a course called BIP. Since learning in BIP is measured by the acquisition of specific programming skills, a learning curve for skill acquisition can be constructed for each student as a function of the number of skills it would have been possible to acquire across the tasks BIP presented in 15 hours of instruction. The slope of this curve is a summary measure of learning rate for each student. There was also a separate posttest, consisting of various programming problems.

The BIP program is designed to keep detailed protocols of each student's learning activities, and these provide intermediate measures to describe individual differences in learning activities that may contribute to success or failure in the course. Table 2 lists 25 learning activity variables of this sort. The list also gives some idea of the kinds of learner control available in BIP. It is a discovery-oriented program in which students schedule their own work, ask for help when they need it or a new task when they want one, and quit tasks any time they wish to do so.

A variety of analyses have been conducted on these data; it is possible here only to touch on the main findings. They were as follows:

1. Individual differences in learning increased over the 15 hour course. The distribution of individual learning curves, shown in Figure 3, depicts this clearly. Learner control of the sort available in BIP seemed not to compensate for these differences, and may actually have helped create such differences to a significant extent.

Figure 3 here

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2. A multidimensional scaling of the correlations among learning activity variables showed a clear circumplex structure, as shown in Figure 4, and suggested several stylistic differences among the students. On the left of the circumplex are activities associated with failure in BIP, while on the right are activities associated with success. At the top of the circumplex are activities that suggest a rapid-fire, argumentative, quitter style, while at the bottom are activities suggesting a slow, methodical, conscientious, checking kind of style. There were, then, strong, indications that learning activity variables could be used to construct learning style profiles for different kinds of learners.

Figure 4 here

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3. Measures of learning activities during the course, learning rate across it, and learning outcome at the end, were strongly predicted from initial aptitude differences among the students. The aptitude measures of most interest as predictors of slope and/or posttest were those representing fluid-analytic ability, perceptual speed, and a personality factor called "independence-flexibility." A clear picture of the trends is given in Figure 4 which maintains the circularity suggested by the circumplex of learning activity measures seen earlier. Each ray of Figure 5 represents a learning activity measure at roughly the same position as it occupied in Figure 4. Each concentric ring of Figure 5 has been assigned to a relevant aptitude or learning outcome measure, as identified in the pie-cut label at the left of the circle.

The correlations between aptitude or outcome measures and the learning activity measures are seen to change relatively smoothly as one moves around

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Figure 5 here

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the circle. Fluid-analytic ability was strongly and negatively related to those learning activities associated with poor performance. Perceptual speed ability was strongly and positively related to many of these same activities. It also seemed to relate positively to activities noted earlier as indicating a rapid-argumentative style, but negatively to the slower methodical style seen before. Independence-flexibility showed some correlations similar to those obtained for fluid-analytic ability. However, there was essentially no correlation between fluid ability and independence-flexibility, so the multiple correlation combining these two variables in predicting slope or posttest would be quite high. Thus, the most successful learners were those showing high scores on fluid ability and independence-flexibility, and low scores on perceptual speed. Verbal-crystallized ability, a traditional predictor of scholastic performance, was not related to learning from BIP, and is thus not shown in the figure.

A summary conclusion seems to follow rather directly from all this. Learner control, as represented in the studies reviewed here at least, does not accomodate individual differences.

Learners always exercise some degree of control over their own overt and covert learning activities during instruction. Instructional treatment variables also, whatever else they may represent, often have different implications for learner control of these activities. Further, individual learners seem to differ in the degree to which they prefer, or are able, to exercise control. Thus, the question of learner control is too simply put if it refers simply to allowing learners to choose their own amounts, sequences, contents, and methods of instruction.

Macroadaptive instruction based on ATI and microadaptive instruction of the sort available in response-sensitive computerized instruction are distinguishable,

yet complementary. One can design broadly different streams of instruction geared to measured aptitude differences, with response-sensitive decisions made along the way in each. Further, information on prior aptitudes can be used to extra advantage in the minute-to-minute decisions of the response-sensitive computer, while the detailed learning history accumulated by the computer on one instructional topic can be joined with external sources of aptitude information in planning the molar instructional units to come. The various possible kinds of learner control should be considered in this context.

The idea that learner control can accomodate individual differences rests on two assumptions: one is that all learners know what is best for themselves at any given moment in an instructional sequence; the other is that all are capable of acting on this knowledge. These assumptions are false! One can perhaps give control to all of the learners some of the time, and to some of the learners all of the time. But one cannot give control to all of the learners all of the time. The problem is to determine which learners to give control to when. This is an ATI research problem not different in kind from those reviewed by Cronbach and Snow (1977). It deserves attention using the methodology established in that tradition. But it does not deserve to be touted as the next panacea.

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Table 1

Degree of Learner Control	Educational Goals and Contents: Elected by Individual	Imposed by Institution Content Variable	Imposed by Institution Content Fixed
I a. Complete independence, self-direction and self-evaluation. Library resources available.	Adult Scholar Model		
b. As above, but with periodic external checks, e.g., tests.			
c. As above, but with resource consultants, peer discussion, and counseling avialable.		Maastricht Study	
II a. Imposed tasks, but with learner control of sequence, scheduling, and pace of learning. Alternative instructional treatments available for choice by learner.		Preference Studies BIP Study	
b. As above, but alternative instructional treatments are imposed by optimization rules.		Atkinson Study	
c. As above, but without alternative instructional treatments.		Greene Study	
III a. Fixed tasks, with learner control of pace. Remediation available.		PI Studies	
b. As above, without learner control of pace. Remediation available.			
c. As above, without remediation.			Child Robot Model

Table 2

Description of BIP Learning Activity Variables

BIP Variables	Definition
N. Tasks seen	Total number of BIP tasks seen (max=90)
P. Task success	Proportion of tasks seen which are completed successfully
P. Task difficulty	Proportion of tasks seen on which BIP rates the student as having difficulty
P. Not understood	Proportion of tasks seen on which the student reports not understanding
P. Arguable	Proportion of tasks seen during which the student 'argues' with BIP that his/her program is satisfactory
P. Model program	Proportion of tasks seen during which the student requests a model program solution
P. Represents program	Proportion of tasks seen during which the student requests a flow chart representation of programming steps
P. Demonstration	Proportion of tasks seen during which the student requests a demonstration of BIP's program showing input and output
P. Scratch	Proportion of tasks seen during which a student scratches program and begins again
P. Hints before 1st line	Proportion of tasks seen during which a student requests at least one hint prior to writing the first legal line of a program
P. Some hints	Proportion of tasks seen during which a student requests at least one, but not all, hints
P. All hints	Proportion of tasks seen during which a student requests all available hints (range=0-5 per task)
P. Quit	Proportion of tasks seen that a student quits

(continued)

Table 2
(continued)

P. Quit w/all hints	Proportion of tasks seen that a student quits after requesting all hints
P. Quit w/out hints	Proportion of tasks seen that a student quits without requesting any hints
P. Success test	Proportion of tasks seen during which a student tests different input cases after his/her program runs successfully
P. Failure test	Proportion of tasks seen during which a student tests different input cases or parts of the program, after program fails to run
P. Data test	Proportion of tasks seen during which a student uses BIP input data after program fails to run
P. Partial test	Proportion of tasks seen during which a student runs sections of program prior to completing entire program
P. Help	Proportion of tasks seen during which student uses one or more help aids (e.g. help, hint) after an error
P. Time planning	Proportion of total time which is spent prior to writing the first legal line of program
P. Time implementing	Proportion of total time spent writing program (time from first legal line to program check)
P. Time debugging	Proportion of total time spent debugging program after it fails to run (time from program check to task exit)
Mean time per task	Average amount of time in minutes spent per task
# skills acquired	Total number of skills which BIP determines have been learned by the student (max=93)

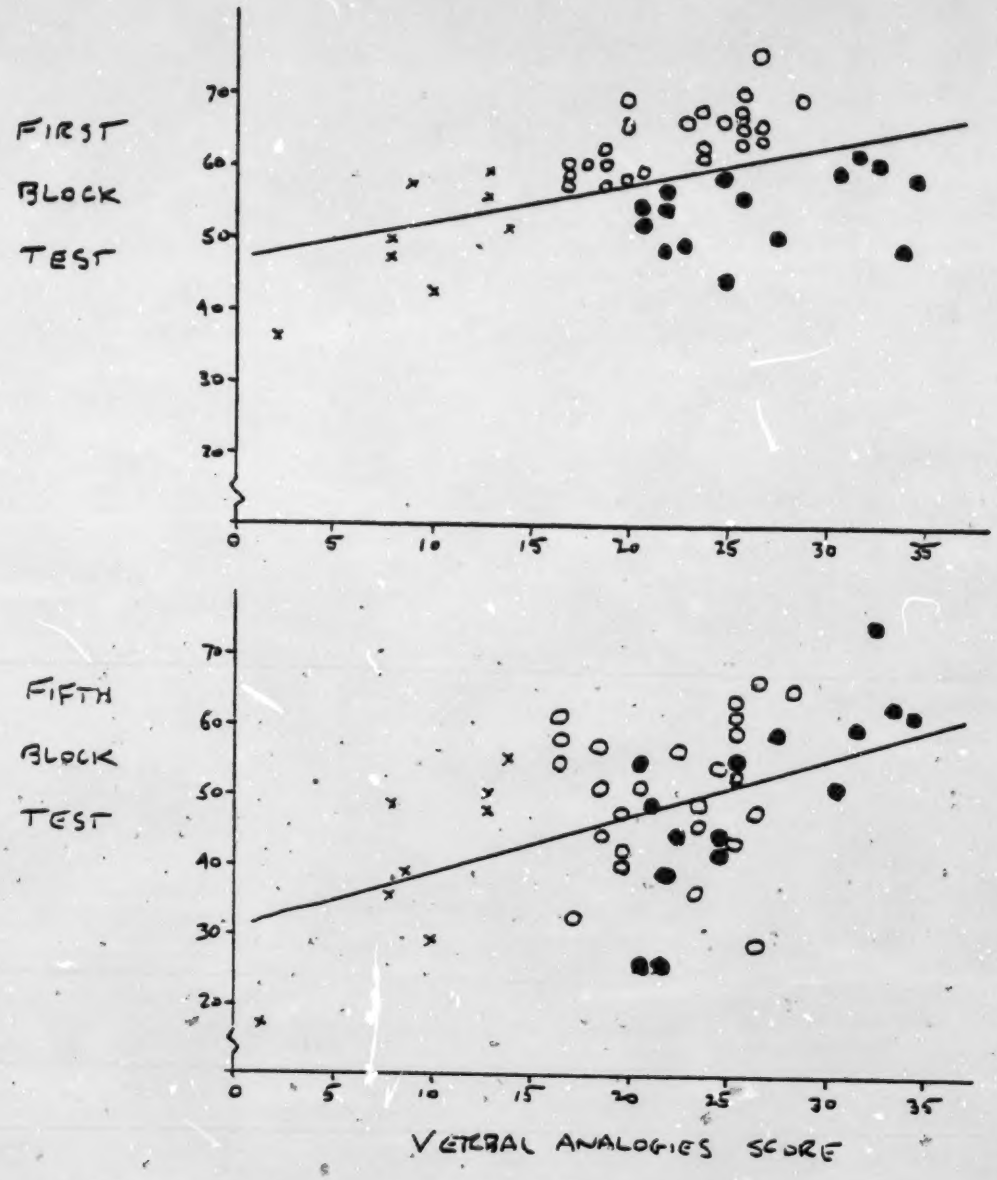

FIG 1 MAASTRICHT STUDY

● = ABLE STUDENTS INITIALLY LEARNING LESS THAN PREDICTED

O = ABLE STUDENTS INITIALLY LEARNING MORE THAN PREDICTED

X = LESS ABLE STUDENTS

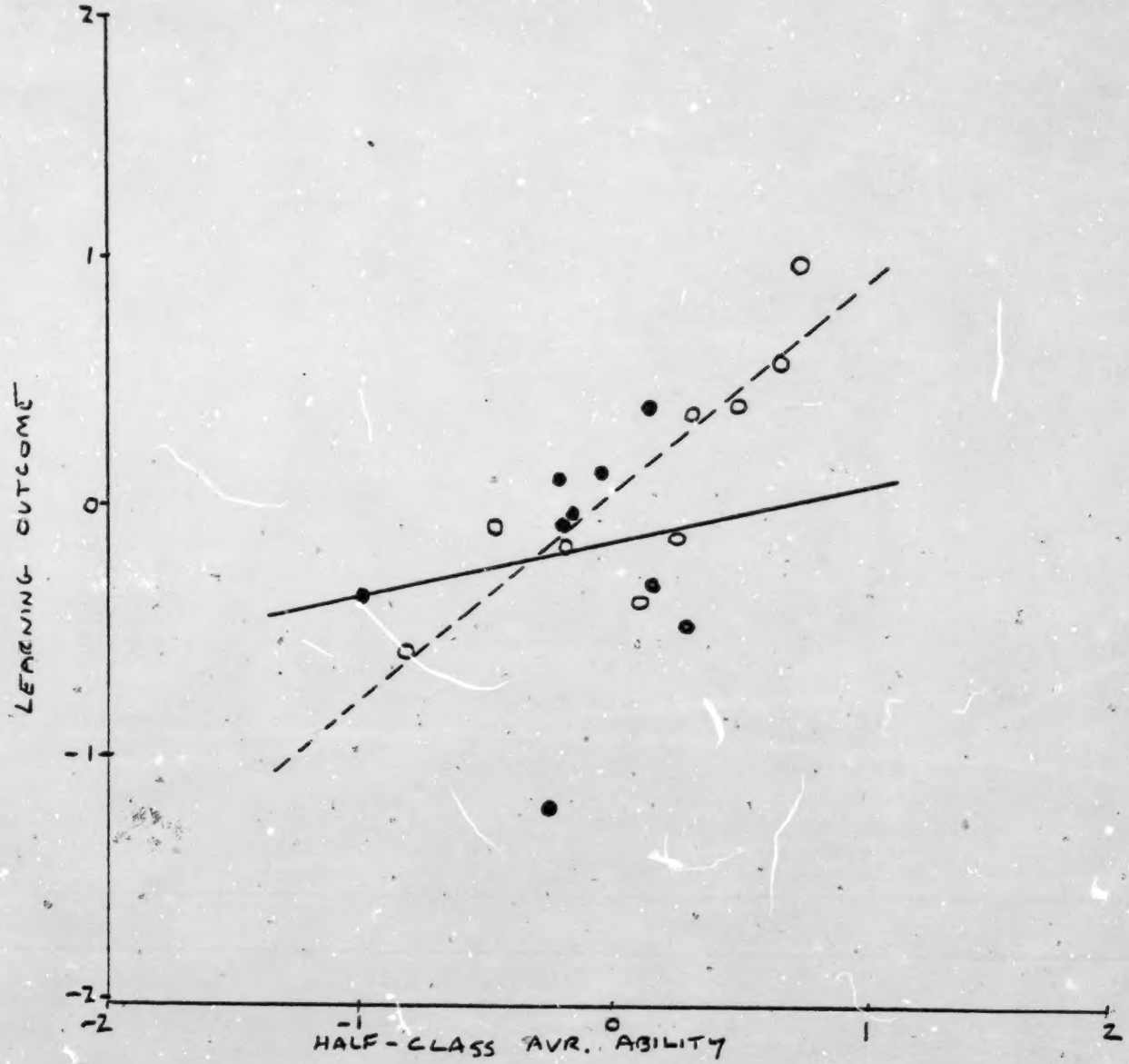

FIG 2 GREENE STUDY

—●— BETWEEN CLASS REGRESSION FOR NO-CHOICE TREATMENT

---O--- BETWEEN CLASS REGRESSION FOR CHOICE TREATMENT

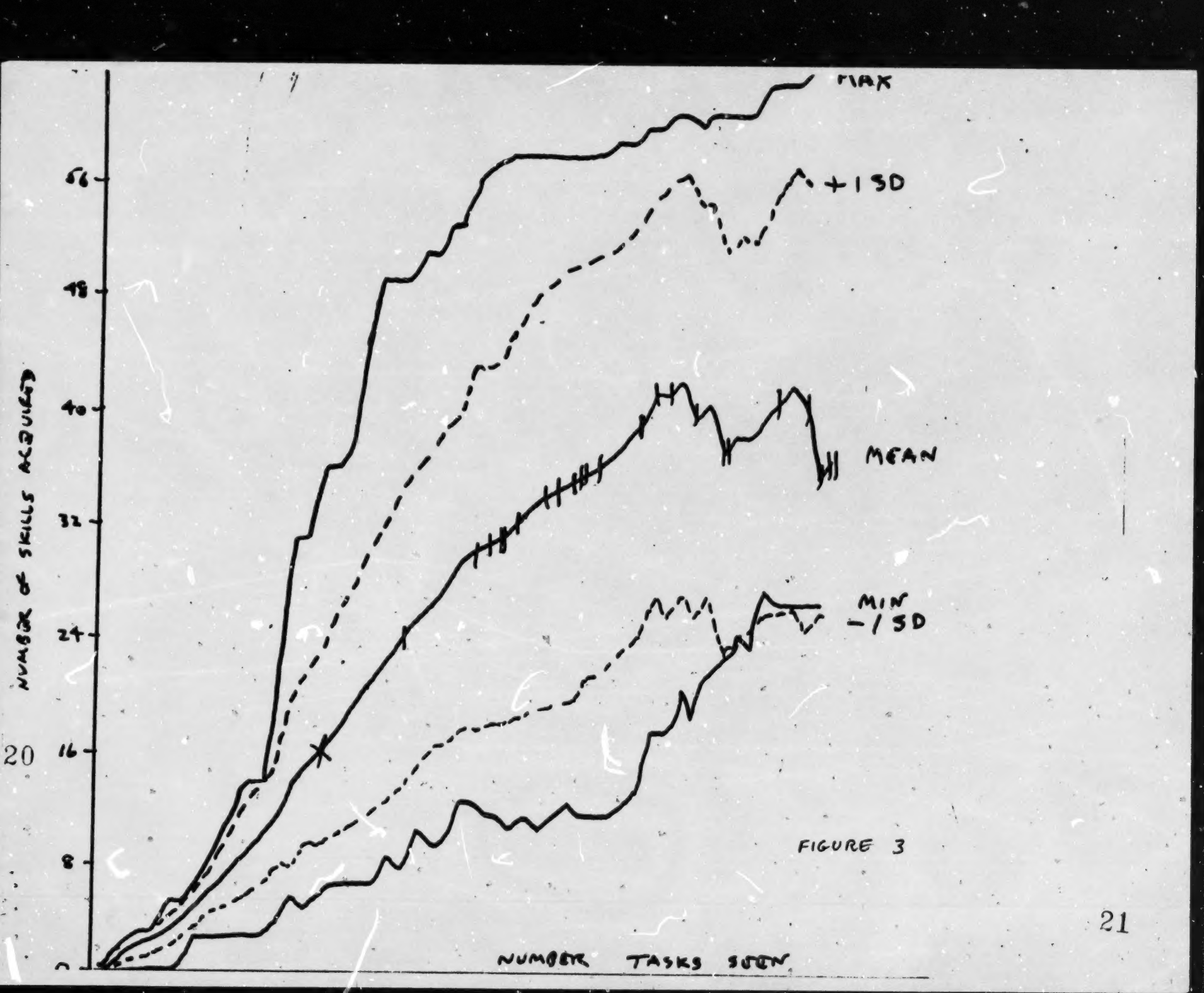
MAX
+1 SD
MEAN
MIN
-1 SD
NUMBER OF SKILLS ACQUIRED
NUMBER TASKS SEEN
56
48
40
32
24
16
8
0

FIGURE 3

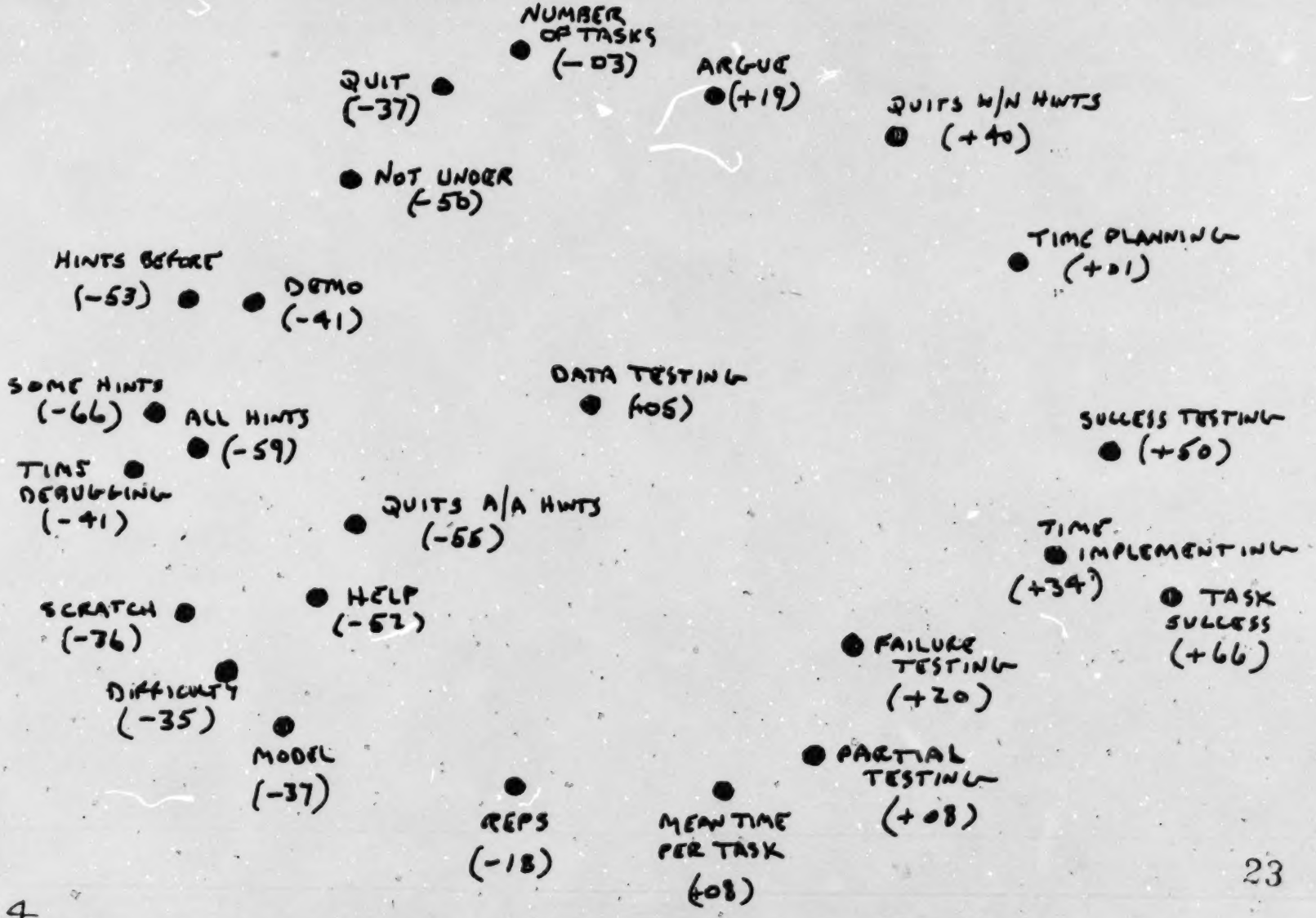
NUMBER OF TASKS (-03)
QUIT (-37)
ARGUE (+19)
QUITS W/N HINTS (+40)
NOT UNDER (-56)
TIME PLANNING (+01)
HINTS BEFORE (-53)
DEMO (-41)
DATA TESTING (+05)
SOME HINTS (-66)
ALL HINTS (-59)
SUCCESS TESTING (+50)
TIME DEBUGGING (-41)
QUITS A/A HINTS (-55)
TIME IMPLEMENTING (+34)
SCRATCH (-76)
HELP (-52)
TASK SUCCESS (+66)
FAILURE TESTING (+20)
DIFFICULTY (-35)
MODEL (-37)
PARTIAL TESTING (+08)
REPS (-18)
MEAN TIME PER TASK (08)

FIGURE 4

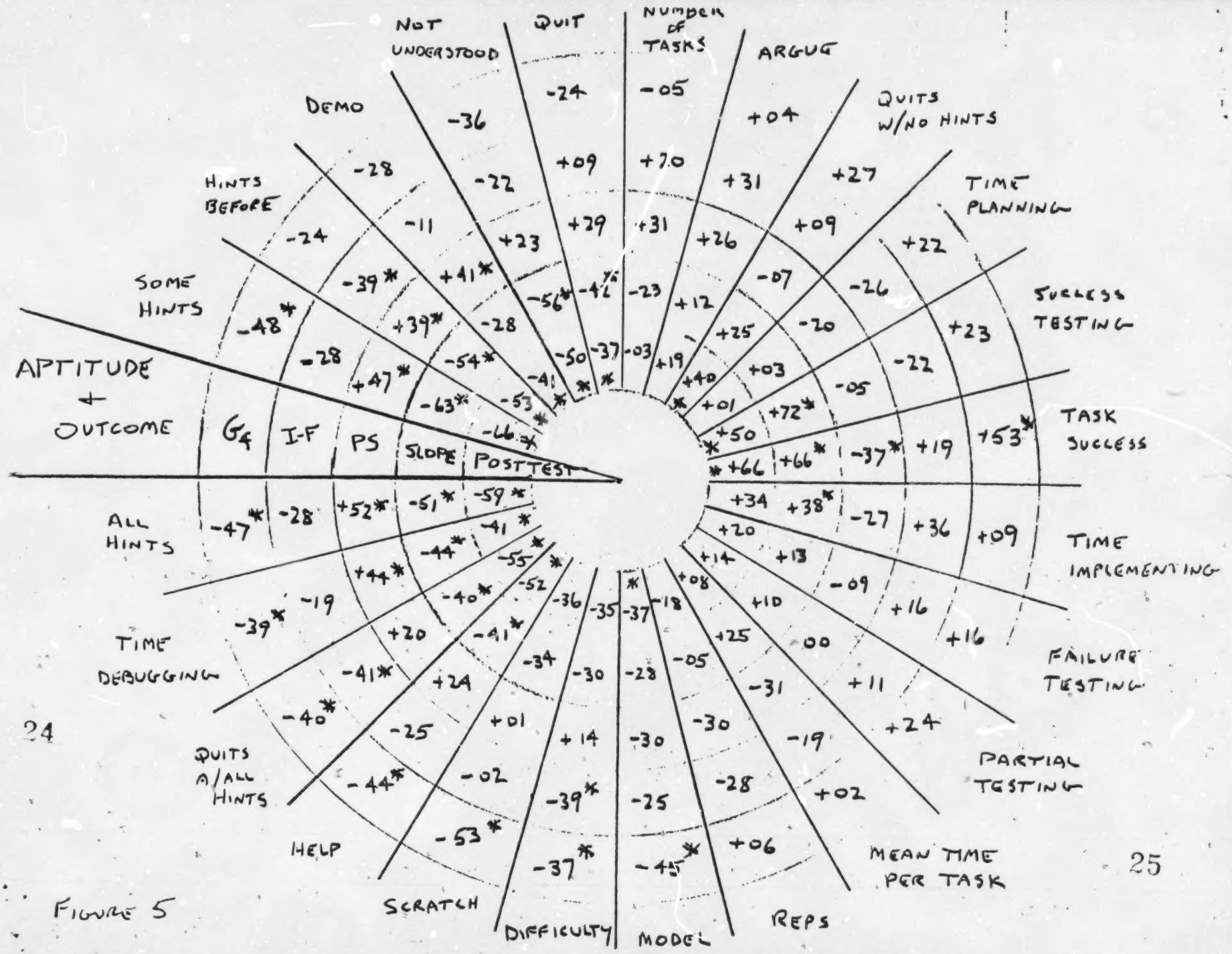

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FIGURE 5